Team project overview

Our team is developing an autonomous book classification and reshelving system for library environments, consisting of a 6-DOF robotic arm, a perception subsystem using an RGB-D camera, and a task planning module. The system works in batch mode: books placed in a collection bin are identified via barcode or visual labels, then the arm retrieves each book and places it onto a shelf after detecting available gaps and selecting optimal slots. The project integrates computer vision, motion planning, and mechanical design to achieve a complete pick-and-place workflow with a target success rate of over 90% and a total cycle time of under 10 minutes for five books.

Individual responsibilities and role in the greater project

I am responsible for the mechanical structure of the gripper – a three-finger configuration specifically designed for handling books in densely packed shelves where direct side grasping is infeasible. My tasks include defining the gripper type, designing the finger geometry and actuation mechanism using a single servo motor, specifying high-friction contact surfaces, and integrating the gripper with the robotic arm's wrist. I also coordinate with the electronics teammate to ensure proper mounting of the servo and with the software teammate to implement the two-stage grasping control logic. My work directly enables the arm to securely extract and place books without damage or slippage.

Design considerations

The primary design considerations are grasping force, adaptability to book thickness, and mechanical simplicity. I chose a three-finger layout where the upper finger inserts into a gap between books to partially extract the target, creating clearance, while the two lower fingers then close from both sides to clamp securely. This two-stage strategy avoids the need for complex side grasping in narrow spaces. Since the initial design review, I have made several changes: simplified the actuation to a single servo instead of a dual-motor system, added mechanical stops to prevent over-compression of books, and replaced a parallel-jaw design with the three-finger configuration for better extraction capability. I also increased the friction surface by adding a silicone rubber pad on each finger to improve grip without excessive clamping force.

Diagrams

The mechanical design is documented with CAD assembly drawings and a detailed gripper subassembly diagram. The main assembly drawing shows the gripper base plate, the three finger, the servo motor mounting bracket, and the linkage mechanism that converts servo rotation into coordinated finger motion. An exploded view illustrates how the servo shaft connects to a gear train that drives the upper finger extension and the lower finger closure simultaneously. A separate finger detail drawing includes dimensions for the curved contact surface and the recess for the silicone friction pad. For control logic, I provided a pseudocode flowchart of the two-stage grasping sequence: first, position upper finger to insert into gap; second, apply controlled pulling force while monitoring servo current; third, close lower fingers; fourth, verify clamp by checking position feedback. PCB designs are handled by another teammate, but I contributed a mechanical layout sketch showing how the gripper integrates with the arm's wrist and where the limit switch is placed to detect full closure.

Testing/Verification

My test plan followed modular and system-level verification.

Week 1: mechanical range test – measure jaw opening and closing spans under no load, verify that the gripper can accommodate book thickness from 10 mm to 50 mm.

Week 2: static grip test – clamp books of different thicknesses and apply a pulling force using a spring scale; record the force at which slippage occurs. The results showed that with silicone pads, the

gripper held all books up to 8 N pull without slipping, exceeding the required 5 N for a 300 g book.
Week 3: cycle test – perform 500 open-close cycles at full speed, measuring joint wear and alignment every 100 cycles; misalignment remained under 0.3 mm.
Week 4: system integration test – mount the gripper on the robotic arm and execute 50 pick-and-place attempts on books of varying thickness. The grasp success rate was 96%. For failed tests – two failures occurred with very thin books where the lower fingers could not apply even pressure – my contingency plan was to add a thin foam layer on the inner finger surfaces, which resolved the issue in retesting.

Self-assessment

My individual workload accounts for approximately 30% of the total team effort, as the gripper required three design iterations and multiple 3D-printed prototypes. I initially fell behind schedule by three days when the first prototype's linkage pin sheared under repeated loading, but I caught up by switching to a steel pin and redesigning the bracket for easier assembly. Currently, I am on schedule with all mechanical parts fabricated and integrated. The overall project is progressing well; the gripper has been validated in sub-system tests and is ready for the final end-to-end demonstration.

Plans for remaining work

Remaining tasks include: replacing the temporary PLA prototype fingers with PETG or nylon for higher durability – scheduled for two days of printing and post-processing. Conducting a final endurance test – 1000 cycles on a 40 mm book at full speed, to be completed within two days. Documenting the final gripper design with an updated bill of materials and assembly instructions for the final report one day. My ambitious goal is to reduce the gripper's response time from 0.6 s to 0.4 s by tuning the servo acceleration profile, but the realistic objective is to maintain reliability at the current speed because faster closure may increase collision risk in tight shelf gaps. I will set a hard deadline for all mechanical work three days before the final presentation to allow buffer for integration and any last-minute adjustments.